

Water Tables, Evapotranspiration, and Climate Variability: A Decade of Observations From Semi-Arid Riparian Ecosystems

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Introduction, Sites, and Methods

- Native cottonwood (*Populus deltoides*) ecosystems in the semi-arid Rio Grande floodplain of central New Mexico are threatened by hydrologic alterations and highly competitive invasive vegetation, e.g., saltcedar (*Tamarix chinensis*) and Russian olive (*Eleagnus angustifolia*).
- Long-term monitoring of shallow alluvial water tables (WTs) and evapotranspiration (ET) in native, non-native, and mixed stands along the river reveals how water availability affects these ecosystems during a decade of extreme climate variability.
- Since 2000, we have instrumented monitoring wells and eddy covariance flux towers to produce WT hydrographs and quantify ET at four riparian sites dominated by phreatophytes along the Rio Grande (Figs 1, 2).
- Our research objectives are to examine the effect of variable but mostly dry climate conditions on river flow, WTs, and ET, the relationship between WTs and ET, and how restoration (flooding, removal of invasives) affects water use by these riparian ecosystems.

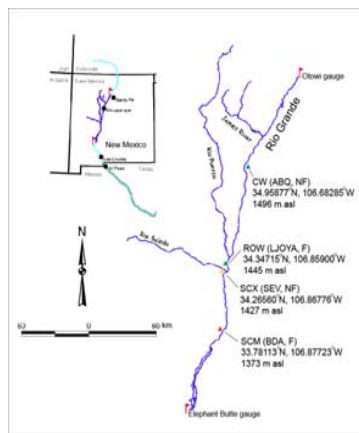


Fig. 1. The middle Rio Grande, New Mexico, USA.

Study sites:

- CW:** Mature cottonwood forest, Albuquerque (ABQ), non-flooding.
- ROW:** Young, emerging Russian olive/willow forest, La Joya State Game Refuge (LJOYA), flooding.
- SCX:** Mature saltcedar xeroriparian stand, Sevilleta National Wildlife Refuge (SEV), non-flooding.
- SCM:** Mature saltcedar monotypic stand, Bosque del Apache National Wildlife Refuge (BDA), flooding.

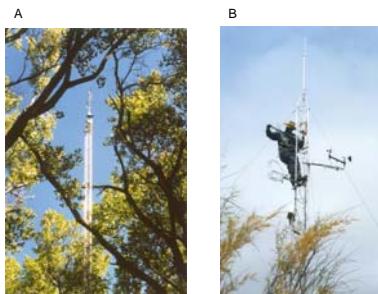


Fig. 2. Eddy covariance ET flux towers. (A) 25 m tower at CW (ABQ). (B) 10 m tower at SCX (SEV).

Results

- The prevailing climate was dry, but highly variable with extreme drought to very wet conditions, affecting surface flows (Fig 3). Snowmelt runoff (Apr. – Jun.) was well below normal (<75%) in 7 of 10 years, and well above normal ($\geq 150\%$) in 2 of 10 years.
- Annual ET responded to drought except at CW (Fig 4).
- WTs ranged from -4 m depth to flood stage and fluctuated dramatically at ROW and SCM but were greatly dampened at CW and SCX and generally reflected climate conditions and river flows, except at CW (Fig 5).
- Within each site, total growing season ET declined with deeper WTs, with strong correlations at ROW and SCM (Fig 6). Between sites, mean WT depth was not a good indicator of ET. Mean growing season WT ranges of 1.6 - 2.3 m and range to depth ratios (R/D) of 1.5 - 1.6 occurred at these sites, vs. 0.5 - 0.6 m and 0.3 R/D at CW and SCX.
- During the historic spring snowmelt runoff period, flooding occurred at ROW and SCM in 2005 and 2008. ET increased significantly at ROW in flooded vs. dry spring runoff years, but was not different at SCM in flooded or dry years, including the spring drought in 2006 (Fig 7).
- Partial restoration at CW by removing its dense, invasive understory resulted in an estimated water savings of 18% the following year (Table 1). The savings diminished to 7% the second year, as regrowth of invasives went unchecked.

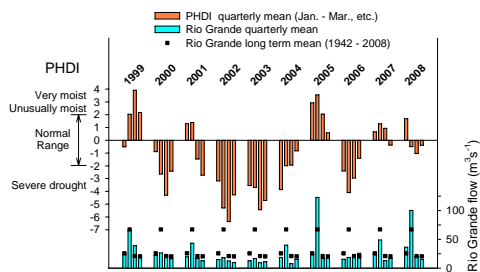


Fig. 3. Quarterly means of the Palmer Hydrological Drought Index, New Mexico Region 2, and Rio Grande daily discharge at the USGS Albuquerque gauge.

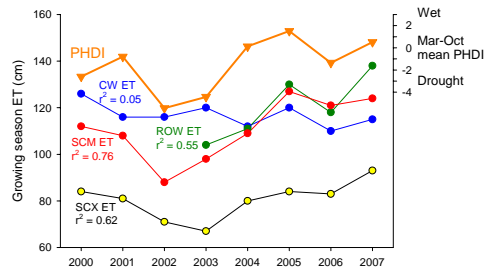


Fig. 4. Mar. – Oct. mean Palmer Hydrological Drought Index, New Mexico Region 2 and growing season ET.

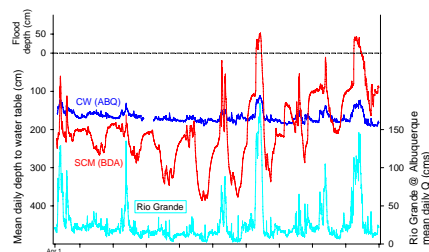


Fig. 5. Mean daily depth to WT (CW and SCM center wells) and Rio Grande discharge at the USGS Albuquerque gauge.

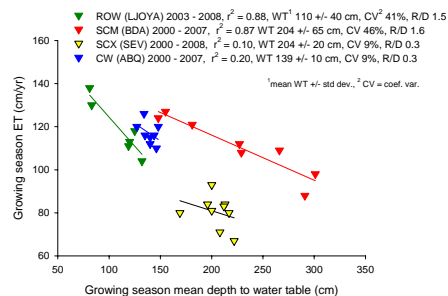


Fig. 6. Mean WT depth vs. ET over several growing seasons. R/D is the seasonal range to mean depth ratio.

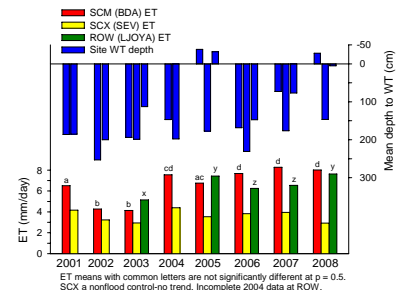


Fig. 7. Mean depth to WT and daily ET during peak runoff (11 May – 15 Jun.). Flooding completely inundated SCM in 2005 and 2008, and ROW in 2005, which was inundated or saturated in 2008.



Fig. 8. SCM (BDA) during flood, June 2005.

Discussion

- The variable and dry conditions observed over the past decade will likely become more typical of the western USA. Decreased and altered runoff coupled with rising depletions due to climate change and population growth can be expected to lower riparian WTs along much of the Rio Grande corridor. However, WTs and ET may be less affected where seasonal groundwater level fluctuations are more stable, e.g., in locations near municipal return flows and irrigation controls at CW and to a lesser extent, SCX.
- In mixed phreatophyte communities, dynamic WTs, which expose a greater extent of vadose zone throughout the growing season, may play a more important role than mean depth itself in transpiration rates.
- Flooding helps establish native riparian vegetation and appears to increase ET in young, emerging communities, but not necessarily in all phreatophyte ecosystems. In years when drought indices indicate sufficient water resources, runoff managed to allow flooding and elevated WTs could be a useful tool in areas targeted for restoration. Concomitant flooding into saltcedar forests would not likely result in excessive water consumption.
- Removal of the dense, non-native understory as a component of restoration at CW resulted in water savings. Regrowth of non-natives greatly diminished the savings by the following year. Sustained restoration efforts are necessary to maintain native ecosystems and salvage water.
- Climate change is expected to exacerbate water scarcity in this region and further challenge restoration. Long term monitoring of WTs and ET reveals how variations in water availability affects these systems and optimizes efforts to sustain and restore native riparian ecosystems. Long term data identify sites with suitable water table hydrographs, i.e., sufficiently shallow during seasonal drawdown and extended droughts yet dynamic enough to flood in order to recruit and sustain native communities and ecosystem functioning. Additional benefits of restoration such as water salvage can also be detected.

Acknowledgements

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Table 1. Growing season ET at the CW site before, after clearing, and during regrowth of invasive (salt cedar, Russian olive) understory vegetation.

Year(s)	ET (cm)	Remarks
2000-2003	120 (mean)	Dense, invasive understory.
2003	120	Dense, invasive understory. Cleared late 2003.
2004	112	Post-restoration, w/ understory removed. ET decreased 7% from 2003, with 18% salvaged relative to SCX, SCM, ROW sites (11% mean increase).
2005	120	Understory regrowth. ET increased 7% from 2004, with 7% salvaged relative to SCX, SCM, ROW sites (14% mean increase).